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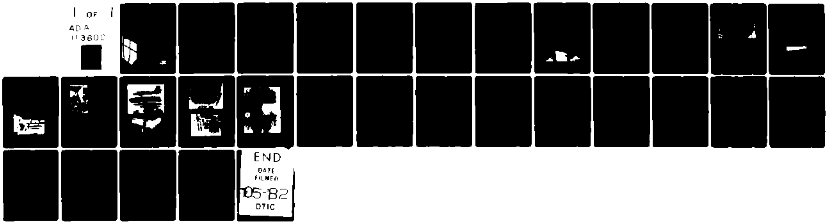

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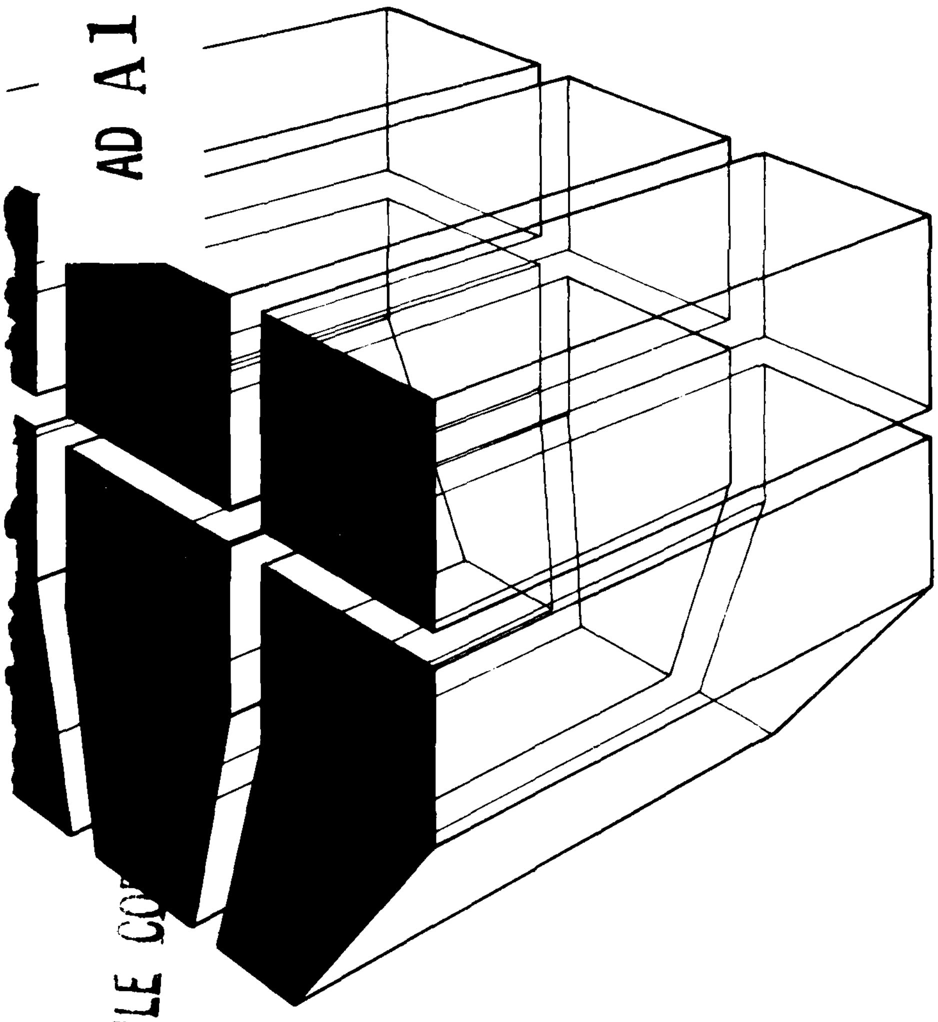
TECHNICAL REPORT M-308
February 1982



# INSULATION RETROFIT UNDER LOW-SLOPE ROOFS



by
Myer J. Rosenfield
Donald E. Brotherson





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This investigation was conducted to identify and evaluate complete systems for applying insulation to the underside of existing low-slope roofs. Criteria were developed to evaluate several systems identified by a market survey. Of the systems evaluated, it was found that only six meet the requirements for this type of application: two are sprayed systems, two are board-applied, and two use proprietary accessories to attach the system to the structure.

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## FOREWORD

This investigation was performed by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL) at the request of the U.S. Department of Energy (DOE). The work was completed under Interagency Agreement No. DE-AI05-800R20724. Mr. George Courville was the DOE Project Monitor.

Appreciation is expressed to B. K. Miles and the late James N. Robinson of the Union Carbide Corporation, Oak Ridge, TN, for their assistance in the investigation, and to Mr. Philip B. Shepherd of the Johns-Manville Corporation for performing the surveys.

Dr. R. Quattrone is Chief of CERL-EM. COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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## INSULATION RETROFIT UNDER LOW-SLOPE ROOFS

# 1 INTRODUCTION

### Background

Millions of square feet of low-slope roofs have little or no thermal insulation to minimize heat losses and gains. Many of these roofs are on "metal buildings," which have steel frames with steel decking supported on purlins (see Figure 1). Many low-slope roofs use a bar-joist/steel-deck structural system, while others use wood or concrete. These buildings can be thermally upgraded if the owner is willing to remove the existing roof system and apply a new roof-insulation system. Sometimes, all or part of the existing roof-insulation system can be salvaged.

An insulation retrofit system that applies the material below the deck is needed for buildings where budget or other considerations prohibit the above-deck approach. These buildings exist in all parts of the country and have many uses (e.g., a classroom, a maintenance building, or a warehouse). Such a variety of uses demands that the retrofit system fulfill many requirements. For example, moisture resistance, fire resistance, appearance, and impact resistance are characteristic needs which will vary with occupancy and climate. In addition, the cost and longevity of a system will affect decisions about whether it should be installed.

The National Program for Building Thermal Envelope Systems and Insulating Materials, which is directed by the U.S. Department of Energy (DOE) and managed by Union Carbide Corporation's Nuclear Division, is identifying and evaluating commercially available products that can be used to thermally upgrade low-slope roofs from the underside. The DOE requested technical support for this project from the U.S. Army Construction Engineering Research Laboratory.

### Objective

The objective of this report is to identify and develop criteria to evaluate commercially available products and proven techniques for installing insulating systems to the underside of low-slope roof structures.

### Approach

Three major tasks were performed to accomplish this objective:

1. The market was surveyed to identify all commercially available systems or techniques that could be used to thermally enhance the roof system without disturbing or removing the existing roof covering. A preliminary analysis was made of all such systems, using technical merit and applicability as criteria; significant and/or appropriate systems were then selected for further evaluation.

2. Selected systems were evaluated using criteria specifically developed for this study. This included site inspections of the products or techniques (where feasible), interviews with users and installers, an analysis of manufacturers' literature, and where possible, a determination of installed costs.

3. The data obtained in Tasks 1 and 2 were summarized and documented.

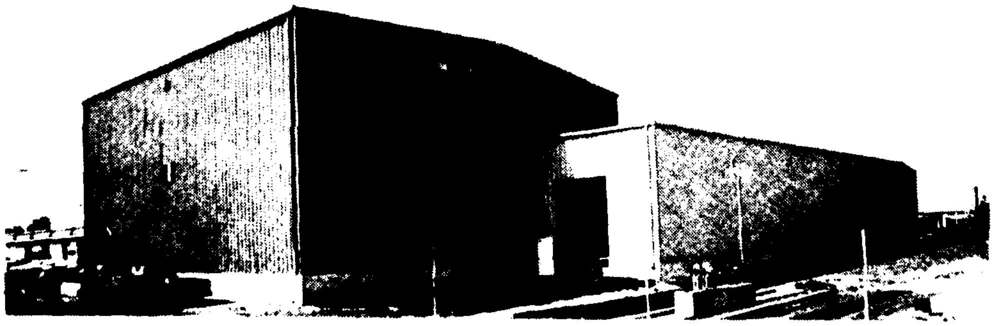

**Figure 1.** Typical metal building. (From *Energy Saving Insulation Systems for Pre-Engineered Metal Buildings* [Celotex], p 3.)

**Scope**

This investigation was limited to systems applied to the underside of the existing roof system. No attempt was made to evaluate the systems other than reporting their attributes; i.e., their applicability to specific projects was not appraised.

# 2 LITERATURE AND MARKET SURVEY AND CRITERIA DEVELOPMENT

**Literature Survey**

The literature was surveyed to identify products and systems currently used or being developed for insulation retrofit. Three computer search sources were used to locate appropriate literature: (1) National Technical Information Service (Springfield, Virginia), (2) Compendex Engineering Index, Inc. (New York, New York), and (3) Ismec Data Courier, Inc. (Louisville, Kentucky).

**Market Survey**

A mailing list of manufacturers, trade associations, distributors, and technical professionals was compiled; a questionnaire requesting input for the market survey was then sent to each. (See Appendix A.) Sixty responses were received. Of these 32 had applicable products available. Most of these positive respondents provided trade literature or technical information about their products. Investigators also reviewed section 7.15 of *Sweet's Catalogue*[1] (1960 through 1980) for other products and/or systems.

Several telephone and personal interviews with manufacturers of insulating materials, trade association officials, members of the National Research Council (Canada), and the Sweet's Division of McGraw-Hill (trade literature) supplemented the mail survey. The market survey was extended to Europe, Australia, and Japan through overseas contacts.

**Criteria Development**

To evaluate the literature and market survey results, criteria for comparing the various identified products and applications were established. It was very difficult to quantify the criteria because there are few similar requirements. For example, toxicity of fumes from burning insulation may be a concern in certain occupancies; however, there are no accepted test methods for establishing toxicity levels. For many of the criteria, owner or occupancy requirements will govern the acceptance or rejection of a product or system. The quality of "appearance" is a good example of this. In residential, office, or other spaces used primarily for personnel occupancy, the surface appearance will be more important than in industrial spaces, where, for example, chemical reaction to the interior environment may be emphasized. For commercial space, a product's cost vs. its life-expectancy may be the governing criterion.

The following 17 criteria were established for evaluating the products or systems. These criteria represent the most common requirements encountered in the field. Appendix B contains the detailed information obtained from field personnel from which the criteria were developed. (The order of their listing does *not* reflect their relative importance in the evaluation procedure.)

1. Thermal value conductivity or resistance. The property of insulation which determines the retention of heat within the building.

2. Moisture effects on thermal value. Resistance may depend on the moisture content of the insulation.

3. Aging effects on thermal value. Resistance may tend to change as the insulation ages.

4. Temperature effects on thermal value. Conductivity is a function of temperature, and affects insulating value.

5. Water vapor transmission rate. A high rate may cause an accumulation of moisture within the material, which may affect its resistance.

6. Effect of exposure on performance. Resistance may tend to change with length of exposure.

7. Physical shape: boards, batts, loose, etc. Affects method of installation.

8. Weight. Must be considered when supporting insulation from existing structures.

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[1] *Sweet's Catalogue File* (McGraw-Hill Information Systems Co.).

9. Compressive strength. May be necessary to resist compressive forces of fastening devices.

10. Reaction to chemicals. Some chemicals in atmosphere may change resistance values.

11. Fire resistance qualities. Insulation should resist burning.

12. Toxicity of fumes from burning. May be important if building being insulated is occupied.

13. Appearance. Important if exposed to view in occupied spaces.

14. Method of application. Should be considered based on occupancy requirements of building.

15. Compliance with building codes. Required in order to obtain building permits.

16. Cost. How will initial cost affect amortization?

17. Other (e.g., life expectancy, years in use, etc.).

# 3 SURVEY RESULTS

### Literature Survey

The computer retrieved 312 citations. Of these, 58 appeared to be of value; however, upon review, only a few produced pertinent data. Several articles pointed out potential problems with condensation, and some provided guidelines for balancing the amounts of insulation above and below possible vapor retarders. One article[2] described new systems for thermally upgrading metal buildings, in which mineral fiber insulations are supported on special hardware designed to interface with the steel purlins of the deck system. Investigators identified three possible sources for these systems and requested information from them for the market survey.

### Market Survey

The market survey revealed many ways of thermally upgrading existing roof systems. Unfortunately, very few products that can be used under the roof deck are available; most require alteration or removal of the existing roof covering. Perhaps the most important finding of the market survey was that the "under deck" market was primarily controlled by the insulation installers, not by the roofing contractors. Only two manufacturers have developed a complete system, and only one of these systems is currently being marketed. In all other cases, the installer/applicator assembles or fabricates a system from products of different manufacturers.

The survey identified six "systems": two are sprayed, two use board stock, and two use proprietary accessories to attach the system to the underside of the structure. These systems are described in detail in Chapter 4.

# 4 DESCRIPTION OF SYSTEMS

### Sprayed Cellulose

Two systems apply cellulose insulation by spraying (see Figure 2).

Thermocon Insulation, manufactured by Thermo Products Company, is a cellulose material with a density of about 2.5 lb/cu ft (40 kg/m$^3$). An adhesive material (Thermobond) is added to bond the cellulose to the surface and to provide a monolithic surface. When tested in 1974 according to UL 723 specifications[3], the material exhibited a flame spread rating of 5 and a smoke-developed rating of 0. The test data indicated a thermal resistance R-value ranging between 4.44 and 5.53 per inch (25.4 mm) thickness at 3.23 to 3.26 lb/cu ft (51.7 to 52.2 kg/m$^3$) density and an R-value of 3.89 at 2.6 lb/cu ft (41.6 kg/m$^3$). The advertised R-value is 4.59 at 2.5 lb/cu ft (40 kg/m$^3$).

National Cellulose markets a product similar to Thermocon. However, test data generated by the Thermal Insulation Manufacturer's Association (TIMA) indicate thermal values that are substantially lower than the data for Thermocon given above. (See Appendix C.)

### Board-Applied

The Celotex Corporation markets a foil-faced insulation board which has a glass-fiber-reinforced, polyisocyanurate plastic core. The plastic foam core

[2] "Hidden Market: Insulating Metal Roofs," *Roofing, Siding, and Insulation*, Vol. 57 (October 1980), pp 74-76.

[3] Standard Test Method for Fire Hazard Classification of Building Materials, UL 723 (Underwriters' Laboratory, October 1979).

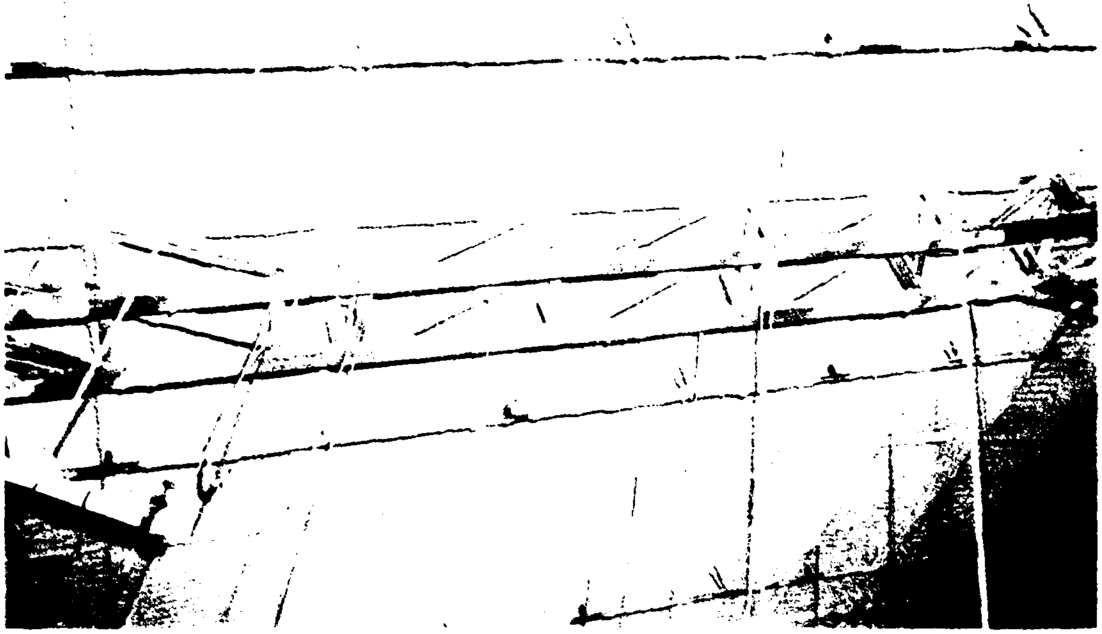


**Figure 2.** Sprayed cellulose insulation.

has a uniform cellular structure. The aluminum facings provide vapor retarders and are available in the following finishes for different applications:

| | |
|---|---|
| Embossed | –white-coated and embossed one side; aluminum on the other side; washable; recommended for exposed applications. |
| Heavy-Duty | –white-coated on foil facer for exposed locations where greater contact resistance is needed. |
| Thermax Plus | –white-coated with 0.019-in. (0.48-mm)-thick aluminum sheet laminated to one side; recommended for areas subject to physical abuse. |
| Satin Finish | –smooth, white-tinted finish; least expensive; washable; recommended where appearance is not of prime importance. |
| Plain Factory & Cavity Wall | –recommended for concealed applications. |

The boards are available in thicknesses ranging from 1/2 in. (13 mm) to 2 1/4 in. (57 mm). The standard width is 4 ft (1220 mm) with lengths up to 40 ft (12.2 m) available. Thermax Plus is also available in thicknesses of up to 3 in. (76 mm).

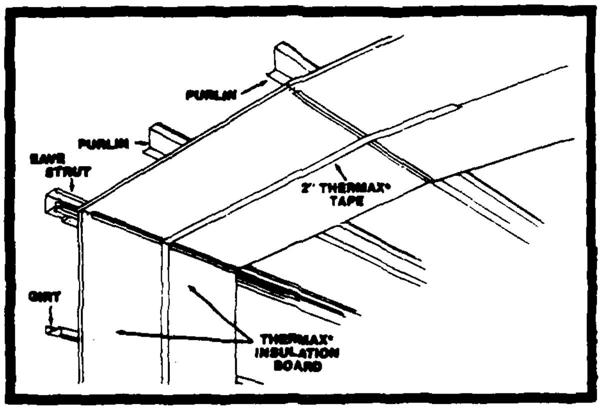
Aged R-values for the product are 7.2 at 75°F (24°C) mean temprature, 8 at 40°F (4.5°C), and 6.5 at 110°F (43°C).

The recommended application technique uses either self-tapping fasteners to secure the boards

directly to the roof purlins (Figure 3), or a suspended grid system (Figure 4). Washers prevent damage to the board surface. The joints are then covered with a pressure-sensitive aluminized tape for vapor retardation. Supplemental glass fiber batts may be installed above the boards to further increase R-values.

Lisi America, Inc., markets a rigid foam board made of phenolic resins (Isophenol). As with isocyanurates and urethanes, a fluorocarbon blowing agent is used to expand the plastic. The material is produced in densities ranging from 2 to 4 lb/cu ft (32 to 64 kg/m$^3$) with an R-value of 5 at 2.5 lb/cu ft (40 kg/m$^3$) density. It is usually supplied in 2- X 3- X 4-ft (610- X 915- X 1220-mm) "buns," or in slabs of any thickness. The boards are rigid with a smooth finish but are relatively fragile and will shatter or break easily. The material will not absorb water or support

**For New Construction and Retro Fit of Existing Buildings. Installation of Thermax® Insulation Board Below Roof Purlins and Inside Wall Girts**




**Note:**
Where Thermax Insulation Board is installed below roof purlins, venting provisions are advised. Adequate venting can be achieved at eaves and ridge.

**Figure 3.** Celotex system for direct fastening to roof purlins. (From *Energy Saving Insulation Systems for Pre-Engineered Metal Buildings* [Celotex], p 12.)

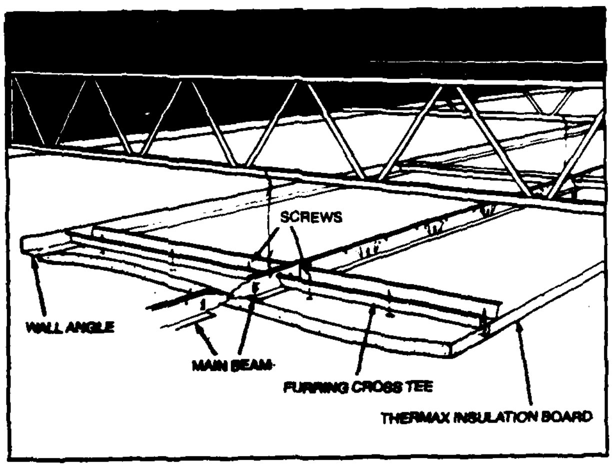



**Figure 4.** Celotex suspended grid system. (From *Energy Saving Thermax Grid Suspension System for Commercial Buildings* [Celotex], p 2.)

combustion, is resistant to chemicals, and is non-corrosive to metals. The boards are designed to be applied using mastics as adhesives (Figure 5).

**Proprietary Accessories**

Two systems use patented accessory devices to install the insulation system.

The Johns-Manville Corporation's "Money-Clip" system is a vinyl extrusion that clips onto the roof purlins and supports a fiberglass board with a vinyl facing and a 5 1 2-in. (140-mm)-thick, low-density, fiberglass insulating batt. End caps and T-sections for joining panels complete the accessory package (Figure 6).

The installed system provides an R-value of about 20. It has a high-impact-resistant surface with a low permeance rating and a white surface for good light reflectance. The appearance is "clean," since no fasteners are visible (Figure 7). The manufacturer claims that this system can be installed quickly.

The Owens-Corning Fiberglas (OCF) Corporation's "Energy Miser" system is particularly designed for metal buildings (Figure 8). The system uses a clip that attaches to the roof purlin and supports a metal roller. The roller-clip assembly can be adjusted to support a variety of insulation thicknesses without compressing them at the purlin points. The insulation is OCF "Certified R Faced Metal Building Insulation" available in R-6 or R-13* thickness. The cavity above the insulation can be filled with additional insulation ranging from 3 to 6 in. (75 to 152 mm) thick.

The manufacturer indicated that the system offers good moisture vapor control, although no provision is mentioned for sealing joints between adjacent runs of insulation. This system was announced as being ready for distribution in June of 1981.[4]

**Contractor-Designed Systems**

The survey identified several contractor-designed systems that use various types of mechanical fastening devices, in which either adhesive-applied pins or stud-welded pins are attached to the underside of the deck. Batt-type insulation is than pushed onto the pins and secured by washers applied over the pins. Sometimes chicken-wire is applied below the insulation to give additional support.

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*Refers to insulation capabilities

[4] *Roofing, Siding, Insulation*, Vol 58 (June 1981), p 50.

**Figure 5.** Lisi America Isophenol Board.

**Figure 6.** Johns-Manville "Money-Clip" system. (From Johns-Manville Brochure, PB-46A 9-78, p 1.)

# 5 FIELD AND SITE INVESTIGATIONS

Site inspections or occupant reports about the systems were obtained to supplement the manufacturers' literature and data.

**Sprayed Systems**

The Union Carbide Corporation at Oak Ridge, TN, reported on two installations of sprayed cellulose. In a warehouse building, no problems were reported (Figure 2); however, in a metal building used for sandblasting, the material did not adhere to the metal surfaces and had fallen off in some areas (Figure 9). The failure occurred mainly because of poor surface preparation and failure to seal the insulation surface.

**Board-Applied System**

One application of phenolic resin board was inspected. The building was of concrete construction and originally had 1 1/2 to 2 in. (38 to 51 mm) of cellulose spray-applied to the underside of the concrete deck. Condensation at the deck-insulation interface had caused failure of the application, and it was removed and replaced with 2 1/2 in. (64 mm) of phenolic board. The specifications called for adhesive application; however, incomplete removal of the cellulose material prevented satisfactory bonding of the phenolic boards to the concrete deck, so they were attached using powder-actuated nails driven through cleats. The inspectors noted that the insulation appeared to be too frangible for this type of installation, tending to crack and spall at the fasteners. In addition, there were many gaps between the boards and voids where the material was cored to install hangers for the suspended ceilings.

**Proprietary Accessories System**

The 136th Civil Engineering Flight (Texas ANG) at Hensley Field, Dallas, TX, provided information about J-M "Money Clip" systems installed in a warehouse and an engine maintenance shop. The warehouse had not been insulated when it was originally built and the maintenance shop's original insulation had deteriorated.

Two significant observations were made when the systems were installed. The vinyl extrusions used for the "clips" are sensitive to high heat; as a result, the gas-fired unit heaters that were installed within 5 ft (1.5 m) of the extrusions softened and deformed them. This was corrected by using hangers and cement-asbestos sheets to isolate the unit heaters. There was also some difficulty closing off the joint at the ceiling-sidewall intersection, so the system had to be modified during installation to seal the ends of the insulation. To date, there have been no major problems with either installation.

**Contractor-Designed Systems**

Union Carbide provided information about a building where insulation was supported on chicken-wire between steel bar joists (Figure 10). Pins and washers were used as temporary supports, and the joints between runs of insulation were taped. The chicken-wire provided permanent support.

A similar type of installation was reported at the White Sands Missile Range in New Mexico and at the Kraft Food Plant in Champaign, IL. At White Sands, some of the batts were supported with permanent pins welded to the underside of the steel roof (Figure 11). The Kraft Plant used an adhesive-applied pin, but did not use chicken-wire for support. The pins were clipped after the insulation was installed and then sealed with aluminum tape.

Figure 7. Completed "Money-Clip" installation.

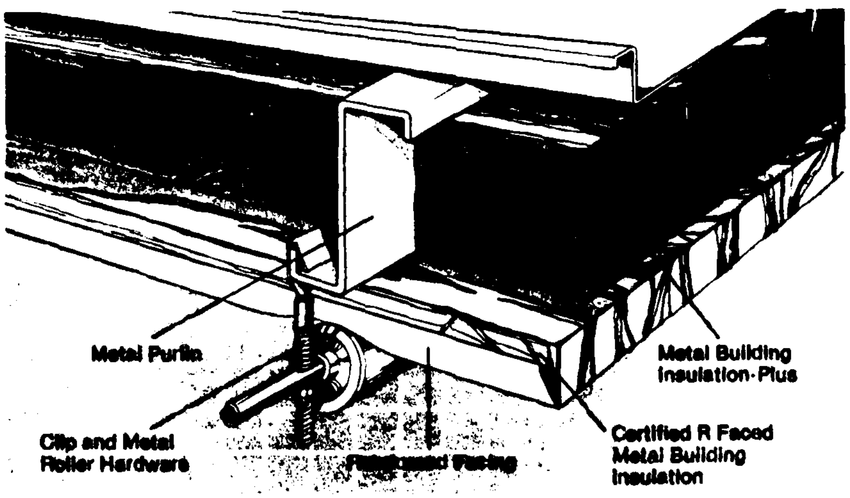


**Figure 8**. Owens-Corning Fiberglas "Energy Miser" system. (From *The Energy Miser System* [Owens-Corning].)

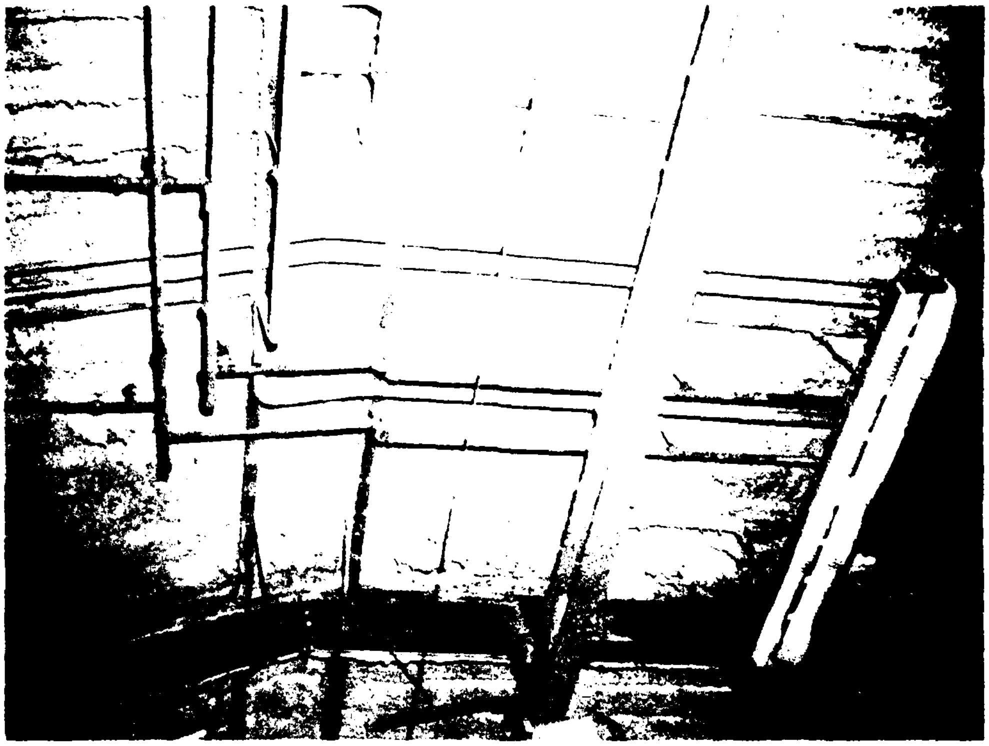

**Figure 9.** Deteriorated sprayed cellulose insulation.

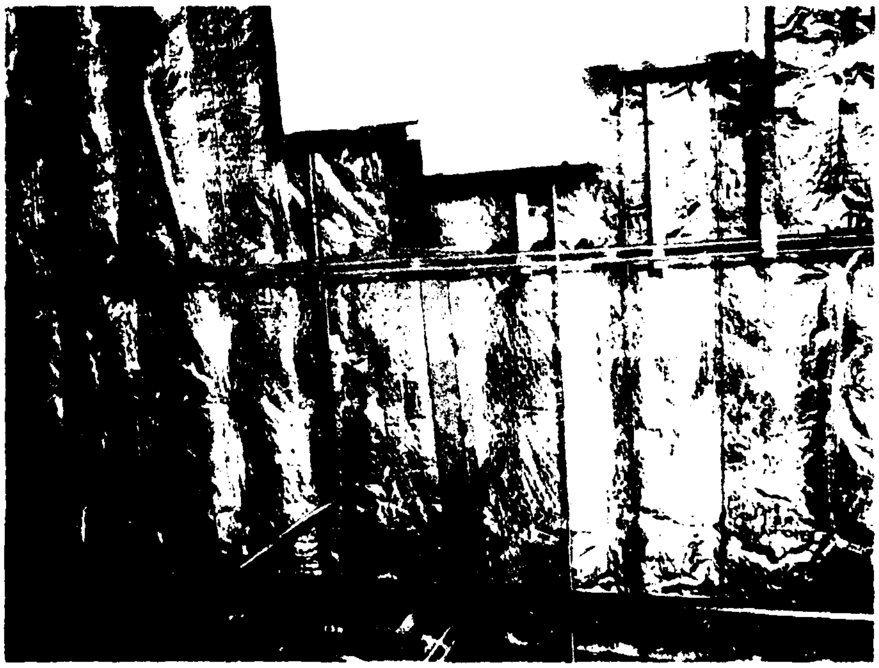

**Figure 10.** Insulation batts supported on chicken-wire.

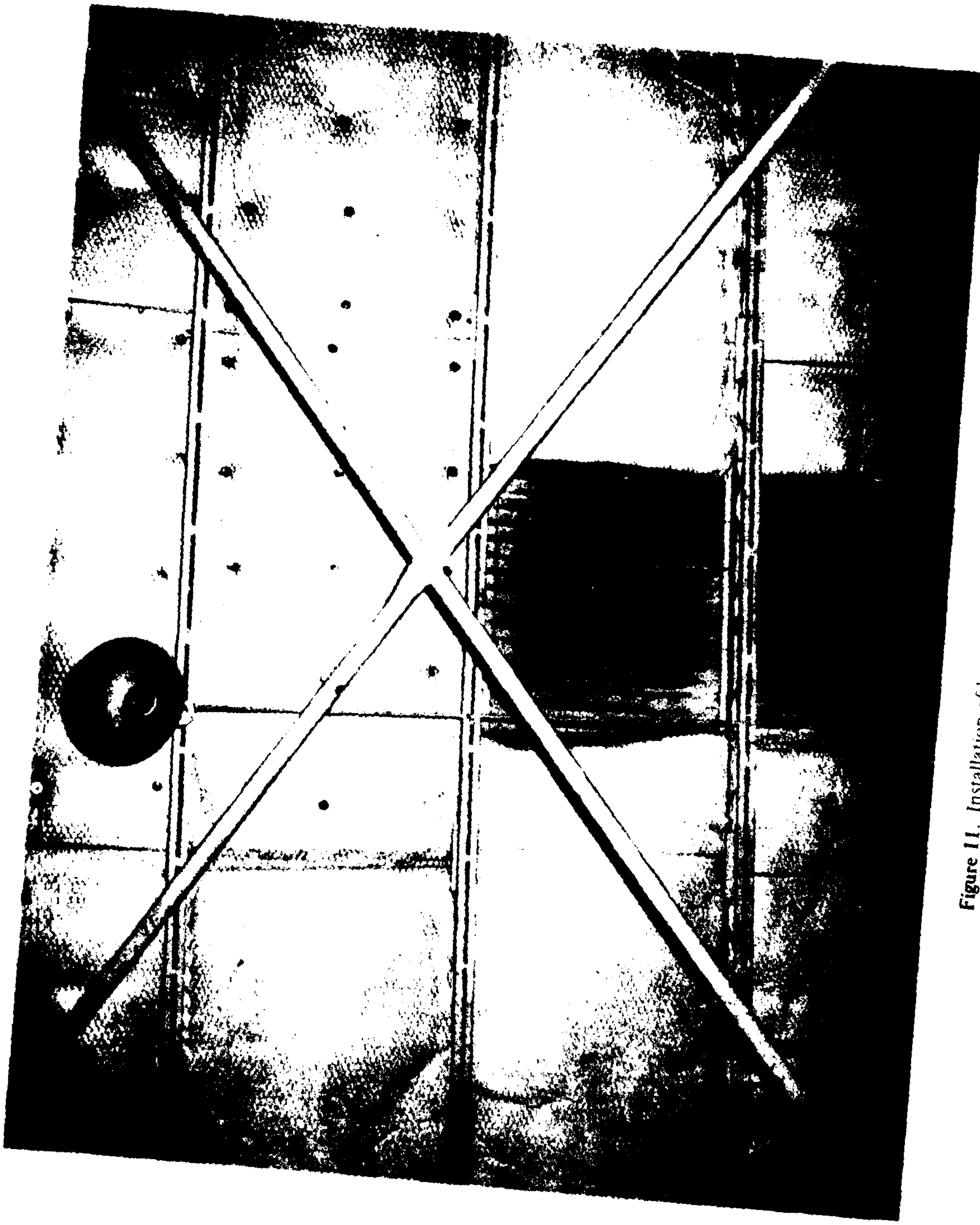

**Figure 11.** Installation of batts at White Sands Missile Range.

# 6 SUMMARY OF SYSTEMS

Table 1 lists the identified systems and products, the data collected, and the data's relationship to the criteria for evaluation.

**Table 1**
**Comparison of Insulation Retrofit Systems**

| | National Cellulose Corporation | Thermo Products Thermocon (Cellulose) | Thermax (Polyiso-cyanurate) | J-M RPMD (Fiberglass) | J-M "Money Clip" | Lisi America (Phenolic) | OCF (Fiberglass) |
|---|---|---|---|---|---|---|---|
| R THERMAL | 4.54/In. | 4.59/In. | 40F: 8/In. 75F:7.2/In. | 2.92/In. | Varies | 4.4-4.9 | Varies |
| MOISTURE EFFECT | | 10-72% After 24 hr @ 90% R.H. | None Vent Space Above | Absorbs | Absorbs | None to Low | Absorbs |
| AGING EFFECT | None | | Sold With "Aged" R-Values | None | None | Stable | None |
| TEMPERATURE EFFECT | 150-180 F | | 100 F to +250 F | | | 350 F Max. | None |
| WATER VAPOR TRANSMISSION RATE | | Permeable | Foam Is Permeable 0.5 "0" Perm With Foil Facers | Permeable Foil Faces Reduce Rate | .05 Perms | Low Absorption Rate | Integral Vapor Retarder |
| EXPANSION EFFECT | | None | None | None | None | Stable | None |
| SHAPE | Loose-4-4.5 In. | Spray | Foil-Faced Slabs 4 ft Wide | Batts W/ Foil Face | Slabs & Batts | Slabs, 2 x 4' 2 x 3' 2 x 3 x 4' bun | Batts & Roll |
| WEIGHT | 2.51 pcf | 2.5 pcf | 2.1-2.3 pcf | | | 2-4 pcf | |
| COMPRESSIVE STRENGTH | | | 25-30 psi | | | 40-60 psi | |
| CHEMICAL REACTION | | Non-Corrosive | | | | Resistant to Acids, Bases, Solvents | None |

Table 1 (Continued)

| | National Cellulose Corporation | Thermo Products Thermocon (Cellulose) | Thermax (Polyiso-cyanurate) | J-M RPMD (Fiberglass) | J-M "Money Clip" | Lisi America (Phenolic) | OCF (Fiberglass) |
|---|---|---|---|---|---|---|---|
| FIRE RESISTANCE | Surface Char. Class I F.S.<25 | FS 10/25 Fuel 5 Smoke 0 | Req. Cover In Sensitive Areas | UL 25/50 | FS 0-25 Smoke 0-50 | FS 5 Fuel 0 Smoke 5 | UL 25/50 |
| TOXICITY | NR*** | NR | NR | NR | NR | NR | NR |
| APPEARANCE | Textured Surface | | Foil-Faced Taped Joint | Foil-Faced | White Scrim | Rigid Plastic | Plastic Face |
| APPLICATION SYSTEM | Spray | Spray W/Sealer | Direct Attach or Grid Susp. | Secured Between Joists | Clipped to Girts | Adhesive | Roll & Clips |
| CODE COMPLIANCE | SS-S-11A HH-I-515D FM-Corner Test UL-Approved ICBO | Corner Test | River-Banks BOCA ICBO SBC FHA #933 | UL HFC 25/50 | | | A11 |
| COST | $0.39/Sq Ft 1 In. | | | R-11:$180/MBF R-19:$259/MBF | 1/2" Board & Batts $1.54/ft² | $0.22-.26 /Bd Ft* $0.40-.47** | |
| OTHER | 15-20 yr Life. Surface Prep Vital | | Not for Resid. Applic. w/o Covering | | | Unlimited Life Exp. | New System |

*For 2 x 4' and 2 x 3' slabs
**For 2 x 3 x 4' bun
***Not Reported

# 7 CONCLUSIONS

Criteria were developed for evaluating the products and systems available for upgrading the thermal properties of low-slope roofs by applying insulation to the roofs' undersides. It was found that these criteria could reasonably be applied to appraise the various systems identified by the market survey conducted during this investigation.

The evaluation showed that only a limited number of products available commercially meet the requirements for this application.

Johns-Manville and Owens-Corning Fiberglas each offer a completely integrated, thermal/finished ceiling system applicable to a prefabricated steel building or similar structure. These systems can accommodate different thicknesses of insulation to match the depth of the existing roof purlins, without any difference in

installation methods. However, only the Johns-Manville system was on the market at the time of the investigation, so it is not possible to compare it with the Owens-Corning Fiberglas system.

The Celotex Corporation offers a foil-faced insulation board. A suspended grid can be used with this product, or it can be fastened directly to roof purlins with self-tapping screws.

Lisi America offers a rigid phenolic foam board designed to be applied using mastics as adhesives. Proper surface preparation is essential to successful installation of this material, as adhesives will not bond to a dirty or dusty surface, and the board cannot be applied to a surface that is not flat. The use of mechanical fasteners may cause the board to spall and break.

Thermo Products Company and National Cellulose both offer cellulose material that can be sprayed in place.

# APPENDIX A: MARKET SURVEY QUESTIONNAIRE

## MATERIAL OR SYSTEM FOR INSULATION RETROFIT OF BUILT-UP ROOFS

Name and Address of Manufacturer(s) ______________________________________________

______________________________________________________________________________

Name of Product/System ______________________________________________________

Describe material/system.

What is it chemically?

Composition

Reactions

Use Restrictions

Age Stability

Reaction to fire

What is it physically?

Shape

Size

Appearance

List physical properties and specifications

List thermal properties and specifications

Age stability

Physical properties

Thermal properties

How is material/system packaged and shipped and stored

Does it influence building appearance

How

Interior

Exterior

Utility of material/system

May the material/system be installed independent of the type of roof construction?

To what types of roof decks and/or roof constructions may the material/system be installed?

What types of roof decks and roof constructions are not suitable for the application of this product system?

Describe how the product/system should be installed.

What auxilliary materials must be purchased for installation of the product/system (such as nails, glue, vapor barrier, etc.)?

List each together with its applicable ASTM, MIL and Federal specs.

Are there any restrictions on application/installation?

Does installation require any cosmetic or structural changes to the building (such as a new BUR membrane, increased height of roof curbs, expansion joints, edges, etc.)?

What special skills or training are required of the installer?

Cost of material/system

What is a typical detailed installed cost by element for your product/system?

What is the anticipated service life of your product/system?

Describe routine maintenance required, its cost and frequency.

With what building codes does the material/system comply?

List all public specifications and standards with which the product/system complies.

ASTM

ANSI

MIL

Federal

Voluntary Product Standard

NFPA

UL

FM

Other

## APPENDIX B: FIELD INFORMATION USED FOR DEVELOPMENT OF LOW-SLOPE RETROFIT INSULATION EVALUATION CRITERIA

### Thermal Properties and Criteria

*Thermal Conductivity*

Select the proper thickness of insulation to provide the desired or specified thermal conductance (conductance = conductivity ÷ thickness).

Make life-cycle cost comparisons of candidate insulations. Note that a simple comparison of installed costs will usually suffice unless regular maintenance of an exposed, decorative surface is a consideration.

*Effect of Moisture on Thermal Conductivity*

There are no public test methods for this quality. Compare suppliers' or published data on candidate insulations. Personal judgment based on anticipated climatic and environmental exposure should be used.

*Effect of Age on Thermal Conductivity*

There are no public test methods for this quality, except Federal Specification HH-I-530, which applies to urethane and isocyanurate insulations. Compare suppliers' or published data on candidate insulations. It is suggested that the time rate of change in thermal conductivity in the installed environment shall not exceed that for polyurethane foam panels faced on two sides with aluminum foil.

*Effect of Temperature on Thermal Conductivity*

Manufacturers of thermal insulations may report thermal conductivity measured at different temperatures. Thermal conductance values for different insulations should be compared only when testing was done at the same temperature.

### Physical Properties and Criteria

*Shape*

This is for information only.

*Dimensions*

Frequently for information only. Thickness of above-deck insulation may require reconstruction of roof edges, curbs, gutters, etc.

*Weight*

Frequently for information only Sometimes it may be necessary to consider the effect of added weight on the load-bearing capabilities of the present deck and support structure. Building code references to roof loading may sometimes be a consideration.

*Strength and Rigidity*

Frequency for information only. It may be necessary to consider certain aspects of strength in some applications where one or more of the following pertain:

1. The insulation will bridge an unsupported span

2. The insulation will carry a load from foot or wheel traffic.

3. The insulation will interface with the support of roof top or ceiling fixtures.

*Chemical Reactions*

The insulation shall not decompose or give off noxious or toxic fumes under normal service conditions which shall include exposure to liquid water

The insulation shall not have a corrosive reaction with materials it may contact during normal service conditions and anticipated service life.

*Reactions to Fire*

The insulation shall comply with local building code and pertinent insurance requirements for performance in fire resistance tests. Such tests may include ASTM E 84 for materials installed below the roof deck and Underwriters' Laboratories or Factory Mutual Tests for materials installed above the roof deck.

Toxicity of fumes and ease of extinguishing are also of concern, but there are no accepted test methods for these qualities.

### Appearance of Installed Product/System

Does the product affect the appearance of the building? Describe the effect, if any.

*Criteria for Inside Exposure*

Color and surface texture shall be selected by the purchaser.

Depth, weight, thickness, and appearance of attachment shall be approved by the purchaser.

*Criteria for Outside Exposure*

Changes in roof edge height, curbs, and parapets shall be approved by the purchaser.

Describe in detail how the material/system is applied.

*Material/System Installed Below Roof Deck*

Is the material/system fastened to the roof deck?

How?

Is the material/system suspended below the roof deck?

How?

Is it supported?

What vapor retarder requirements are introduced by the material/system?

What ventilation requirements are introduced by the material/system?

Describe in detail how the material/system is applied.

*Product/System Performance*

Describe all available guarantees or warranties. What is the anticipated service life of the product/system?

*Specification and Code Compliance*

List building code(s) compliance. List specifications and standards compliance.

*Packaging, Shipping and Storage (information only)*

Size of shipping container.

Number of pieces per package (does not apply to bulk insulation).

Coverage per package in square feet.

Weight per package.

Number of packages per truckload.

Number of packages per carload.

Storage instructions.

## APPENDIX C: TIMA TESTS ON SPRAYED CELLULOSE INSULATION

### SUMMARY
### TIMA SPRAYED CELLULOSE TESTS
### THERMAL AND WATER VAPOR TRANSMISSION

### I. THERMAL TESTS

*EQUIPMENT* - Calibrated Hot Box as described in ASTM STP 544, 1974. Test area nine feet by fourteen feet; cold side at 0 F, warm side at 75°F.

*MATERIAL* - Sprayed Cellulose was applied (by Manufacturer A or B) to a full scale roof section composed of a typical metal building roof sheets attached to three nine foot purlins spaced five feet on centers. Fastener spacing when testing Manufacturer A was two per foot and when testing Manufacturer B product was one per foot. In both tests, the intended applied thickness was to be 1 1/2".

*TEST RESULTS* - Manufacturer A at an average thickness of 1.92" and an average density of 5.3 pcf.

Initial "R" Value - 4.1
"U" Value - 0.24
After Ten Days Conditioning*
"R" Value - 3.2
"U" Value - 0.31

Manufacturer B at an average thickness of 1.95" and an average density of 5.3 pcf:

Initial "R" Value - 4.4
"U" Value - 0.23
After Ten Days Conditioning*
"R" Value - 3.1
"U" Value - 0.32

*Conditioning was accomplished by exposing the insulated roof section to an environment of 75°F and 50% RH with a 0°F temperature on the opposite side of the roof section. The average moisture absorption as measured by per cent increase in insulation weight was 84% for Manufacturer A and 120% for Manufacturer B.

### II. WATER VAPOR TRANSMISSION TESTS

*EQUIPMENT* - Full scale WVT test fixture for measuring daily moisture gain to 1.0 lb. on a five foot by ten foot test section; cold side at 0°F, warm moise side at 75°F, 50% RH.

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